USE OF PRODUCT DESIGN METHODOLOGY TO DEVELOP THE TECHNICAL AUDIT PROTOTYPE FOR WEBSAT

Pallavi Dharwada, Nikhil Iyengar, Kunal Kapoor, Joel S. Greenstein & Anand K. Gramopadhye
Department of Industrial Engineering
Clemson University
Clemson, South Carolina

Data analysis tools are effective in evaluating various processes and identifying problematic areas. Safety being the primary concern of the aviation industry, it is imperative that effective data analysis be conducted on data obtained from various aviation processes. WebSAT is a web-based surveillance and auditing tool which is intended to capture errors from aviation maintenance processes and analyze the data to further evaluate on the effectiveness of each of the maintenance processes. WebSAT will collect data for the quality assurance work functions of aircraft maintenance, which are surveillance, internal audits, technical audits, and airworthiness directives. This paper presents the product design methodology used to prototype the technical audit module for WebSAT. As a part of the design methodology, customer statements were analyzed and corresponding need statements were generated. These were then used to generate metrics in terms of which product specifications will be established. Concepts were generated for the design of the module and were tested with potential users to identify the most promising one. Later, the selected concept was refined by incorporating features of other concepts that were preferred by the user.

Introduction

The Federal Aviation Administration has continually supported human factors research to explore various strategies that improve aviation safety. Aviation maintenance is identified as a crucial factor that contributes to accidents (Boeing and US ATA, 1995) and hence considerable amount of research in past has focused on identifying intervention strategies that enhance the functioning of the aviation maintenance system. Previous research on aviation maintenance investigated issues pertaining to the performance of the inspector or the aviation maintenance technician (AMT). These studies have devised several training strategies, such as on-the-job training (OJT), computer-based training (CBT) and training in a virtual reality environment to improve the efficiency and the effectiveness of the AMT (Nickles et al, 2001). There have also been studies which looked at the psychophysical aspects of the inspector, such as age, fatigue, and cognitive abilities to assess the performance of an inspector on the highly demanding inspection task, where errors have a severe impact on aircraft safety (FAA, 1991).

Various methodologies have been adopted to analyze errors so as to recommend human factors interventions that enhance the safety of an aircraft. Error classification schemes (Patankar, 2002) are very useful for identifying weak points in a system, provided they are backed by comprehensive investigation procedures. In addition to these schemes, empirical models are needed to determine how the parts of the system interact to influence outcomes. A recent example is the Maintenance Error Decision Aid (MEDA) (Rankin et al., 2000). MEDA helps analysts identify the contributing factors that lead to an aviation accident. However, the MEDA process is dependent on the erring technician's willingness to be interviewed about an error. Anything that would decrease this willingness, such as a fear of being punished for the error, would have a detrimental effect on MEDA implementation.

Taylor and Thomas (2003) used a self-report questionnaire called the Maintenance Resource Management/Technical Operations Questionnaire (MRM/TOQ) to measure what they regarded as two fundamental parameters in aviation maintenance: 1) professionalism, which is defined in terms of reactions to work stressors and personal assertiveness and 2) trust, defined in terms of relations with co-workers and supervisors.

All these efforts tend to be reactive in nature, analyzing accidents subsequent to their occurrence. Hence, there is a need for empirically validated models/tools that capture data on maintenance work and provide a means of assessing this data prior to dispatch of the aircraft. The inspection carried out on an airplane by the AMTs is often overseen and audited by the airlines which own the airplane. The data that comes out of these surveillance and auditing processes is an indicator of the efficiency and effectiveness of the maintenance and inspection tasks that are being carried out by the AMT. An appropriate data collection strategy could identify the significant sources of improper maintenance, which would in turn reflect on the efficacy of the aviation maintenance process. Furthermore, the data thus collected can be utilized to conduct analysis and assess risk related factors which would eventually impact the safety of the aircraft. Also, the data analysis could provide valuable information such as error trends specific to a fleet type or a particular vendor which would help the airline management to proactively mitigate risk. However, existing models and schemes often tend to be ad hoc, varying across the industry, with little standardization. In order to address this issue, the devised empirical models and tools must employ standardized data collection procedures, provide a basis for predicting unsafe conditions, and produce interventions that will lead to a reduction in maintenance errors.

To collect the relevant data from disparate sources that supervise aviation maintenance, the research team has proposed to design a system (WebSAT – Web-based Surveillance and Auditing Tool) that performs standardized data analysis while allowing standardized data collection. This research also proposes that standardization in data collection can be obtained by collecting data on variables which effectively measure maintenance processes and eliminate existing inconsistencies. These variables are defined by the research team as *process measures*. Process measures incorporate the response and observation-based data collected from various aviation maintenance processes and facilitate the process of data analysis. This research seeks to collect and present the error causes and occurrences using WebSAT. The industry partner the team is working with is FedEx, in Memphis, TN. The work functions for which data will be captured through WebSAT are surveillance, internal audits, technical audits and airworthiness directives. Dharwada et al. (2004) defined and described the aforementioned work functions in detail. To tailor the WebSAT system to the needs and job roles of the users at FedEx, the team started the development process by following the product development methodology developed by Ulrich and Eppinger (2003).

The research team gathered user requirements with respect to WebSAT in the first phase of the research. During data gathering sessions for the surveillance process, the team observed that the primary responsibility of the quality assurance representatives is to carry out surveillance on work cards performed by the AMT who directly impacts the safety of the aircraft. Collecting data from the surveillance activities performed by these representatives in a standardized way is imperative to identify error trends and mitigate risk proactively. Hence, apart from conducting surveillance, the quality assurance representatives are responsible for categorizing the data obtained into appropriate process measures.

In a similar fashion, the auditors from the technical audits process are responsible for verifying the adequacy of the procedures followed at the vendor's facility with regard to aircraft maintenance. The auditors perform their tasks using different checklists for different vendors, based on the type of vendor. Therefore, WebSAT needs to ensure aggregation of data into the appropriate process measures. For effective functioning of the system, it is very important that the system satisfies the users' needs and supports the accomplishment of their goals.

Within each of the 4 aforementioned work functions, there are two types of users – one at the operator level (e.g., the auditor) and the other at the management level of the work function in the quality assurance department of airline. There is also a third level of user in the hierarchy: the senior manager responsible for the overall adequacy of all the quality assurance functions.

Given the different scenarios that are to be presented to each user, based on their requirements, the design of the system plays a vital role in the accomplishment of the users' goals. Every design decision plays a role in the overall utility of the system in achieving the primary goal of ensuring aircraft safety. There are four modules to design. The current paper focuses on the application of Ulrich and Eppinger's design methodology to design the Technical Audit (TA) Module of the WebSAT prototype.

Methodology

User-centered design methodology enables the development of tools that perform at a high level in the hands of the end user. The user-centered design process is guided by three principles, outlined by Gould and Lewis (1985) in their seminal work in the field.

1. Early and continual focus on users and their tasks. Direct contact with users, including discussion and observation of their tasks and work environment identifies their wants and needs.

2. Empirical testing with users. Users doing real work with mockups and prototypes of product concepts are observed to identify areas requiring revision.

3. Iterative design. The design, based on the results of user testing, is refined to bring the product into

conformance with explicitly stated performance specifications.

These principles are practiced through the application of a variety of user-centered methodologies within a structured design process. Such methodologies include contextual design (Beyer and Holtzblatt, 1998), task analysis (Gramopadhye and Thaker, 1998; Hackos and Redish, 1998), the development and use of personas (Cooper and Reimann, 2003) and scenarios (Rosson and Carroll, 2002), usability inspection methods (Nielsen, 1993), and usability testing (Dumas and Redish, 1993; Rubin, 1994). These practices can be integrated into Ulrich and Eppinger's (2003) structured design process to achieve a methodology that is both user-centered and compatible with current best practice in product design and development.

The design and development methodology proposed by Ulrich and Eppinger can be structured in four phases:

1. Identifying Needs
2. Developing Product Specifications
3. Generating and Selecting Concepts
4. Iterative Prototype Testing

The following sections will explain how the above mentioned phases were carried out to develop the Technical Audit (TA) module of the WebSAT prototype.

Phase I - *Identifying Needs*: The research team used interviews, focus groups, observation sessions and surveys to collect data on the aviation maintenance processes at FedEx. Three members of the team prepared interview questions before hand. These questions were to guide them through the interview process, and were helpful in raising the issues that needed to be studied at FedEx. The techniques of contextual inquiry proposed by Beyer and Holtzblatt (1998) were used as the interview progressed. If the interviewee shared information which was not directly related to the question asked but was relevant to the product, the research team added inquiry into those topics. Process documentation was sought by the team to enhance their understanding of procedures better. Observation sessions helped the team to understand a typical day of the technical auditor. Focus groups conducted with the manager of technical audits and another technical auditor helped the team identify the intricacies of the technical audit process. While one person in the team focused on questioning the users, a second person focused on taking down notes. The third person concentrated more on capturing behavioral gestures, concerns and emotions of the user describing the current system. The team members also switched their roles and, if one of them felt it appropriate to interrupt the process to clarify certain issue, he / she did not hesitate to do so.

Information Gathered on the Technical Audit Process:
There are two types of technical audits: 1) Supplier Audits and 2) Fuel, Maintenance and Ramp (FMR) Audits. Further, in supplier audits alone there are several types of vendors involved. For each type of vendor, the auditors might use just one checklist or more than one. These checklists have questions that evaluate the procedures, regulatory policies, and compliance of the vendors in terms of the requirements of FedEx and the FAA. The data collected from the checklists are responses in the form of Yes, No, Not Applicable, Not-Observed or some open ended comments. The findings obtained are shared with the vendor and the vendor is expected to implement corrective action within a stipulated period of time. The data collected from the technical audit checklists for a particular vendor is reported to the TA manager by the auditors. This report also includes concerns of the auditor and comments with respect to the vendor personnel, the facility or fleet type. The users involved in this work domain are the technical auditor and the TA manager.

Having gathered data on the TA work domain, the team moved towards identifying process measures for the work function. Process measures classify the data collected from the checklists. In order to identify the process measures, the team studied the various checklists that existed for TA. The team also studied the Coordinated Agency for Supplier Evaluation (C.A.S.E) standards which contain a detailed description of the various categories related to vendor evaluation. Using this documentation, the team formulated process measures based on the sections in the checklists (Iyengar et al., 2004).

Phase II – *Developing Product Specifications*: With the material gathered on the work flows, the team discussed the transcribed material and encapsulated the information in the form of work flow diagrams. The team converted each customer statement into need statement. These need statements were grouped based on relatedness and were then arranged in a hierarchy. Each group was given a name, which was considered to be the primary need and all the need statements within that group were termed secondary needs. This hierarchy of primary and secondary needs was sent to the stakeholders to elicit an importance rating for each need. The team members also gave a rating to the needs, based on their understanding of the process. The average of the rating obtained from the team members was compared with the rating obtained from the client and in most cases the ratings were similar to each other. Based on the project scope and team consensus, two needs were eliminated. Every need statement was then converted into a 'metric' which appropriately measured the performance of the product with respect to the need. An example of a customer statement, need statement and its metric is shown in Table 1 below.

Table 1: Conversion of Customer Statement to Need Statement and to Metric

Customer Statement	I would like the tool to provide documentation of corrective actions for Non-Systematic audits.
Need Statement	The tool stores documentation on non-systematic audits.
Metric	Time taken to download the documentation on corrective actions for audits
Unit	Seconds

Having generated metrics, the team started generating design concepts, while working on competitive benchmarking in tandem. Each member in the team generated one concept. Subsequent to the generation of the concept, the team followed the gallery method, using a whiteboard to refine the concept with various ideas of the team members. Depictions of the three concepts are shown in the figures below. Different scenarios were developed with respect to the two types of users. Then the team had brainstorming sessions on the pros and cons of each concept and consequently, attempted to refine each concept further.

Phase III - *Testing*: In this phase the concepts were pilot tested with two faculty members at Clemson University. These were representative users only to the extent that their age matched with that of the users. The testing took place with low-fidelity prototypes, in that the prototypes depicted the features of the concepts, but they were not functional. Prior to testing, the participants were informed about the auditor's job role and responsibilities.

Subsequently, the participants were presented with three scenarios and were asked to point out how they would go about performing the task with each concept. They were asked to think aloud while performing these tasks. The feedback obtained from this testing was documented but was not acted upon before the second phase of testing, which involved testing with real users.

Figure 1: Concept 1- Based on the Google Search Engine but with multiple search criteria.

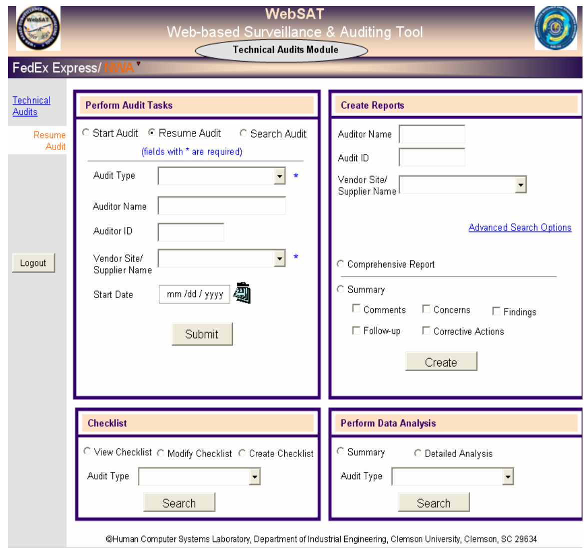

Figure 2: Concept 2 - Based on Microsoft Outlook

Two audit managers were recruited for testing. They signed a consent form before participating in the study. The users were physically located in Memphis, while the experimenters were in Clemson. To enable remote testing, the participants were sent PowerPoint files consisting of storyboards of all the screen shots, with instructions. A scenario was presented to them on one slide and the screens were presented on the next slide. The testing was done during a conference call so that the team could ensure that the users were "on the same page" as the experimenters.

Figure 3: Concept 3 - Based on Tab Metaphor

Figure 4: Final Concept - Tab metaphor of concept 3 combined with data grid of concept 2.

Results and Discussion

The results of the initial testing phase with the faculty showed that the organizational structure of concept three was preferred to that of the other two concepts. These users also mentioned that the grid feature of concept two was easy to understand and intuitive. The results from final testing also showed that concept three was preferred overall. The grid feature of concept two was also preferred by all of the users who participated in the two phases of testing.

One user mentioned that the vendor dropdown for vendor list needed to be constrained based on criteria such as vendor type, as there could be as many as in some cases, 600 vendors. With the feedback obtained from testing, the concepts were further refined and combined. A screen shot of the final concept is shown in Figure 4. Having selected this concept, the team proceeded to develop this concept using Microsoft ASP.NET 2002 and SQL server.

Conclusions

The team still is in the process of competitive benchmarking and setting the target specifications for the product. Subsequent to the development of the product, user testing will take place with representative users to compare the performance of the prototype with the product specifications and drive iterative refinement of the design. After the completion of the TA module, the research team will proceed to the development of the other modules using the same structured methodology. The research team is finding this methodology extremely helpful in developing a product that can positively influence aviation safety.

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